

What is Claimed is:

1. A method for removing at least one of thiophene and thiophene compounds from liquid fuel, the method comprising the step of:

5 contacting the liquid fuel with an adsorbent which preferentially adsorbs the at least one of thiophene and thiophene compounds, at a selected temperature and pressure, thereby producing a non-adsorbed component and a thiophene/thiophene compound-rich adsorbed component, wherein the adsorbent includes at least one of a metal and a metal cation, the at least one of metal and metal cation adapted to form  $\pi$ -complexation bonds with the at least one of thiophene and thiophene compounds, and wherein the preferential  
10 adsorption occurs by  $\pi$ -complexation.

2. The method as defined in claim 1 wherein the adsorbent comprises an ion-exchanged zeolite selected from the group consisting of zeolite X, zeolite Y, zeolite LSX, MCM-41 zeolites, silicoaluminophosphates, and mixtures thereof, the zeolite having  
15 exchangeable cationic sites, wherein at least one of the sites has the at least one of metal and metal cation present.

3. The method as defined in claim 2 wherein the adsorbent is at least one of Cu(I)Y zeolite and Ag(I)Y zeolite.  
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4. The method as defined in claim 2 wherein the at least one of metal and metal cation comprises at least one of  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Cu}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Ga}^{3+}$ ,  $\text{Pd}^0$ ,  $\text{Ag}^+$ , and  $\text{Cd}^{2+}$ .

25 5. The method as defined in claim 1 wherein the adsorbent comprises a carrier having a surface area, wherein the at least one of metal and metal cation is in the form of a monolayer metal compound dispersed on the carrier surface area, the metal compound releasably retaining the thiophene/thiophene compounds; and the carrier comprising a plurality of pores having a pore size greater than the effective molecular  
30 diameter of the at least one of thiophene and thiophene compounds.

6. The method as defined in claim 5 wherein the adsorbent carrier is silica and wherein the metal compound is silver nitrate.

35 7. The method as defined in claim 5 wherein the at least one of metal and metal cation comprises at least one of  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Cu}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Ga}^{3+}$ ,  $\text{Pd}^0$ ,  $\text{Ag}^+$ , and  $\text{Cd}^{2+}$ .

8. The method as defined in claim 1 wherein the method further comprises the step of changing at least one of the pressure and temperature to thereby release the thiophene/thiophene compound-rich component from the adsorbent.

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9. The method as defined in claim 1 wherein prior to contacting the liquid fuel with the adsorbent, the method further comprises pretreating the adsorbent, the pretreatment process comprising the steps of:

activating the adsorbent at a temperature between about 250°C and about 10 600°C in at least one of a dry air atmosphere, air, an inert atmosphere and a reducing atmosphere for an amount of time ranging between about zero hours and about 20 hours; and then

cooling the adsorbent in at least one of a dry air atmosphere, air, and inert atmosphere.

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10. The method as defined in claim 9 wherein the at least one of metal and metal cation is  $\text{Ni}^{2+}$  and wherein pretreating the adsorbent takes place in at least one of a dry air atmosphere, air, and an inert atmosphere.

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11. The method as defined in claim 9 wherein the at least one of the metal and metal cation is  $\text{Cu}^+$  and wherein activating the adsorbent takes place in at least one of an inert atmosphere and a reducing atmosphere, and wherein the cooling takes place in an inert atmosphere.

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12. The method as defined in claim 11 wherein the reducing atmosphere comprises a reducing gas.

13. The method as defined in claim 12 wherein the reducing gas comprises at least one of hydrogen and carbon monoxide.

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14. The method as defined in claim 1, further comprising the step of regenerating the adsorbent by calcining the adsorbent at a temperature and for a length of time sufficient to substantially remove the at least one of thiophene and thiophene compounds.

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15. The method as defined in claim 14 wherein the calcining time ranges between about 0 hours and about 20 hours.

16. The method as defined in claim 14 wherein the calcining temperature ranges between about 300°C and about 600°C.

5                   17. The method as defined in claim 14 wherein the at least one of metal and metal cation is  $\text{Ni}^{2+}$  and calcining takes place in at least one of a dry air atmosphere, air, and inert atmosphere.

10                   18. The method as defined in claim 14 wherein the at least one of metal and metal cation is  $\text{Cu}^+$  and calcining takes place in at least one of a dry air atmosphere and oxygen atmosphere, and wherein regeneration further comprises the step of reducing copper oxidized during the calcination to  $\text{Cu(I)}$ .

15                   19. The method as defined in claim 1 wherein the adsorbent is adapted to adsorb aromatic compounds, and wherein the adsorbent adsorbs the thiophene/thiophene compounds at least slightly more selectively than the aromatic compounds.

20                   20. The method as defined in claim 1 wherein the liquid fuel is at least one of gasoline, diesel fuels, coal and shale derived liquid fuels, methanol, and the like.

21. The process as defined in claim 1 wherein, before contact with the adsorbent, the liquid fuel has a high concentration of aromatic compounds, and a low concentration of thiophene/thiophene compounds.

25                   22. The method as defined in claim 1 wherein the at least one of metal and metal cation comprises at least one of  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Cu}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Ga}^{3+}$ ,  $\text{Pd}^0$ ,  $\text{Ag}^+$ , and  $\text{Cd}^{2+}$ .

30                   23. The method as defined in claim 1 wherein the at least one of metal and metal cation comprises  $\text{Ni}^{2+}$ .

24. The method as defined in claim 23 wherein the liquid fuel comprises diesel fuels.

35                   25. The method as defined in claim 1 wherein the selected temperature and pressure is ambient temperature and ambient pressure.

26. The process as defined in claim 1 wherein at  $10^{-5}$  atm, the adsorbent adsorbs more than about 1 mmol/gram of thiophene.

27. A method for removing at least one of thiophene and thiophene compounds from liquid fuel, the method comprising the steps of:

contacting the liquid fuel with an adsorbent which preferentially adsorbs the at least one of thiophene and thiophene compounds, at a selected temperature and pressure, thereby producing a non-adsorbed component and a thiophene/thiophene compound-rich adsorbed component; the adsorbent comprising a carrier having a surface area, the carrier having a monolayer of a metal compound dispersed on substantially the entire surface area, the metal compound comprising at least one of a metal and a metal cation adapted to form  $\pi$ -complexation bonds with the at least one of thiophene and thiophene compounds, and wherein the preferential adsorption occurs by  $\pi$ -complexation, the metal compound releasably retaining the thiophene compounds; and the carrier comprising a plurality of pores having a pore size greater than the effective molecular diameter of the at least one of thiophene and thiophene compounds; and

changing at least one of the pressure and temperature to thereby release the thiophene/thiophene compound-rich component from the adsorbent;

wherein the liquid fuel is at least one of unleaded gasoline and diesel fuel;

and wherein, prior to contacting the liquid fuel with the adsorbent, the process comprises pretreating the adsorbent, the pretreatment process comprising the steps of:

activating the adsorbent between about  $250^{\circ}\text{C}$  and about  $600^{\circ}\text{C}$  in at least one of a dry air atmosphere, air, an inert atmosphere, and a reducing atmosphere for an amount of time ranging between about 5 hours and about 15 hours; and then

cooling the adsorbent in at least one of a dry air atmosphere and inert atmosphere.

28. The method as defined in claim 27 wherein at  $10^{-5}$  atm, the adsorbent adsorbs more than about 1 mmol/gram of thiophene.

29. The method as defined in claim 27 wherein the at least one of metal and metal cation is  $\text{Ni}^{2+}$  and wherein pretreating the adsorbent takes place in at least one of a dry air atmosphere, air, and an inert atmosphere.

30. The method as defined in claim 27 wherein the at least one of the metal and metal cation is  $\text{Cu}^{+}$  and wherein activating the adsorbent takes place in at least one of

an inert atmosphere and a reducing atmosphere, and wherein the cooling takes place in an inert atmosphere.

31. The method as defined in claim 27, further comprising the step of  
5 regenerating the adsorbent by calcining the adsorbent at a temperature and for a length of time sufficient to substantially remove the at least one of thiophene and thiophene compounds.

32. The method as defined in claim 31 wherein the calcining time ranges  
10 between about 6 hours and about 12 hours.

33. The method as defined in claim 31 wherein the calcining temperature ranges between about 300°C and about 600°C.

15 34. The method as defined in claim 31 wherein the at least one of metal and metal cation is  $\text{Ni}^{2+}$  and calcining takes place in at least one of a dry air atmosphere and inert atmosphere.

20 35. The method as defined in claim 31 wherein the at least one of metal and metal cation is  $\text{Cu}^+$  and calcining takes place in at least one of a dry air atmosphere and oxygen atmosphere, and wherein regeneration further comprises the step of reducing copper oxidized during the calcination to  $\text{Cu(I)}$ .

25 36. The method as defined in claim 27, further comprising the step of adding a guard bed adjacent an inlet to the adsorbent such that the liquid fuel contacts the guard bed prior to contacting the adsorbent.

30 37. The method as defined in claim 36 wherein the guard bed has as a main component thereof at least one of activated carbon, activated alumina, silica gel, zeolites, clays, pillared clays, diatomaceous earth, porous sorbents, and mixtures thereof.

35 38. The method as defined in claim 27 wherein the thiophene compounds include at least one of thiophene, methyl-thiophene, benzothiophene, methyl-benzothiophene, dibenzothiophene, 4-methyl-dibenzothiophene, 4,6-dimethyl-dibenzothiophene, 3,6-dimethyl-dibenzothiophene, and mixtures thereof.

39. The method as defined in claim 27 wherein the at least one of metal and metal cation comprises at least one of  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Cu}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Ga}^{3+}$ ,  $\text{Pd}^0$ ,  $\text{Ag}^+$ , and  $\text{Cd}^{2+}$ .

5                    40. The method as defined in claim 27 wherein the at least one of metal and metal cation comprises  $\text{Ni}^{2+}$ .

41. The method as defined in claim 40 wherein the liquid fuel is diesel fuel.

10                   42. The method as defined in claim 27 wherein the at least one of metal and metal cation comprises at least one of  $\text{Cu}^+$ , and  $\text{Ag}^+$ .

43. A method for removing aromatic compounds from a mixture containing aliphatic compounds and the aromatic compounds, the method comprising the step of:

15                    contacting the mixture with an adsorbent which preferentially adsorbs the aromatic compounds, at a selected temperature and pressure, thereby producing a non-adsorbed component and an aromatic compound-rich adsorbed component, wherein the adsorbent includes at least one of a metal and a metal cation, the at least one of metal and metal cation adapted to form  $\pi$ -complexation bonds with the aromatic compounds, and  
20                    wherein the preferential adsorption occurs by  $\pi$ -complexation.

44. The method as defined in claim 43 wherein the aromatic compounds comprise at least one of benzene and cyclohexane.

25                   45. The method as defined in claim 43 wherein the adsorbent comprises an ion-exchanged zeolite selected from the group consisting of zeolite X, zeolite Y, zeolite LSX, MCM-41 zeolites, silicoaluminophosphates, and mixtures thereof, the zeolite having exchangeable cationic sites, wherein at least one of the sites has the at least one of metal and metal cation present.

30                   46. The method as defined in claim 1, further comprising the step of adding a guard bed adjacent an inlet to the adsorbent such that the liquid fuel contacts the guard bed prior to contacting the adsorbent.